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## POTASSIUM CHLORATE

[3811-04-9]

Formula:  $\text{KClO}_3$ ; MW 122.50

### Uses

Potassium chlorate is an oxidizing agent in matches, fireworks and explosives. The head of safety matches is coated with potassium chlorate which is struck on a surface consisting of red phosphorus, antimony(III) sulfide and an adhesive to light the fire. It also is used in laboratory preparation of oxygen. Its dilute aqueous solution is an antiseptic.

### Physical Properties

Colorless crystals or white granular powder; monoclinic structure; density 2.32 g/cm<sup>3</sup>; melts at 356°C; decomposes at 400°C; moderately soluble in cold water, 7.19 g/100mL at 20°C, solubility increasing with temperature, 57 g/100mL at 100°C; insoluble in acetone and liquid ammonia.

### Thermochemical Properties

|                    |                  |
|--------------------|------------------|
| $\Delta H_f^\circ$ | -95.06 kcal/mol  |
| $\Delta G_f^\circ$ | -70.82 kcal/mol  |
| $S^\circ$          | 34.2 cal/deg mol |
| $C_p$              | 24.0 cal/deg mol |

### Preparation

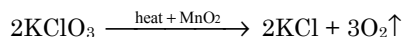
Potassium chlorate may be prepared by mixing concentrated solutions of sodium chlorate and potassium chloride. Potassium chlorate crystallizes when the solubility product  $[\text{K}^+][\text{ClO}_3^{2-}]$  is exceeded.

Potassium chlorate also can be prepared by passing chlorine gas into a hot solution of caustic potash:



### Reactions

Potassium chlorate decomposes on heating below its melting point and in the presence of a catalyst, forming potassium chloride and oxygen. The reaction is catalyzed by manganese dioxide and is used in laboratory preparation of oxygen:



On heating (in the absence of a catalyst) potassium chlorate converts to potassium perchlorate:



Potassium chlorate is a strong oxidizing agent. In aqueous solution, it

exhibits redox reactions of ionic  $\text{ClO}_3^-$ . Many are similar to potassium permanganate (see Potassium Permanganate).

### Analysis

Elemental composition: K 31.91%, Cl 28.93%, O 39.17%. The salt is dissolved in water and the solution analyzed for potassium by AA, ICP, or other techniques. The  $\text{ClO}_3^-$  ion in solution may be identified by ion chromatography.

### Toxicity

The salt is moderately toxic by ingestion and other routes causing irritation of the GI tract and kidney. Also, it can cause breakdown of red blood cells, producing methemoglobinemia.

## POTASSIUM CHLORIDE

[7447-40-7]

Formula: KCl; MW 74.55

### Occurrence and Uses

Several ores containing potassium chloride are found commonly in nature. The principle ores are sylvite, KCl; carnallite,  $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ ; kainite,  $\text{KCl} \cdot \text{MgSO}_4 \cdot 3\text{H}_2\text{O}$  and sylvinite, a naturally occurring mixture of sylvite and halite (common salt). Potassium chloride also is found in sea water at an average concentration of 0.076% (w/v).

Potassium chloride is the most important salt of potassium from the perspective of its abundant occurrence and applications. This salt, along with potassium sulfate, is used heavily in fertilizers as the primary source of potassium, an essential element for crops. Over 90% salt manufactured is consumed as fertilizer. Also, potassium chloride is a raw material for producing potassium metal and several important potassium salts including potassium nitrate, potassium hydroxide, and potassium sulfate. Other applications are in electrode cells; photography; buffer solutions and measurement of salinity in water.

### Physical Properties

Colorless crystals or white crystalline solid; cubic structure; salty taste; density 1.984 g/cm<sup>3</sup>; melts at 770°C; sublimes at 1,500°C; soluble in water 34.4 g/100mL at 20°C, 56.7 g/100mL at 100°C; soluble in ether, glycerol and alkalies; slightly soluble in alcohol.

### Thermochemical Properties

|                    |                  |
|--------------------|------------------|
| $\Delta H_f^\circ$ | -104.4 kcal/mol  |
| $\Delta G_f^\circ$ | -97.8 kcal/mol   |
| $S^\circ$          | 19.7 cal/deg mol |
| $C_p$              | 12.3 cal/deg mol |

## Production

Potassium chloride is produced by several processes. The salt is recovered from natural brine by solar evaporation in shallow ponds. Various methods are employed in mining ores from their natural deposits. Usually it is recovered from sylvinite or a naturally occurring complex mixture of langbeinite and kainite.

Refining potassium chloride is mostly by crystallization and froth flotation processes. Crystallization refining is based on great difference in solubility of potassium, sodium and magnesium chlorides. While potassium chloride at the boiling point of water is much more soluble than at ordinary temperatures, magnesium chloride, on the other hand, is highly soluble even at ordinary temperatures. In contrast, the solubility of sodium chloride varies slightly with temperature.

Fractional crystallization is carried out at temperatures from 30 to 100°C under various modifications of the solution at different stages.

Refining by flotation is more common, accounting for about 80% of potassium chloride produced in the USA. The process involves several steps: (1) ore crushing (2) removal of water-insoluble clays by scrubbing the ore with brine saturated with NaCl–KCl in agitated tanks, (3) hydraulic desliming, (4) reagent conditioning of ore flowing from the hydraulic desliming operations, using various depressants, such as, starch and polyacrylamides, (5) separation of amine-coated potassium chloride grains from sodium chloride by flotation caused by froths from tallow amines, (6) separation of product crystals from process brine by centrifugation, (7) product drying at high temperatures (about 175°C or above), and finally (8) sizing the product, separating different sized particles such as coarse, standard, and suspension-grade materials.

## Analysis

Elemental composition: K 52.44%, Cl 47.56%. An aqueous solution of the salt can be analyzed conveniently for potassium by various wet methods or instrumental techniques (see Potassium). Chloride ion can be determined by ion chromatography or by titration with a standard solution of silver nitrate using potassium chromate indicator.

## Toxicity

Ingestion of large doses can cause irritation of the gastrointestinal tract and nausea. Potassium chloride can stop the heart beat and is a component of lethal injections.

# POTASSIUM CHROMATE

[7789-00-6]

Formula:  $K_2CrO_4$ ; MW 194.20

Synonyms: neutral potassium chromate; potassium chromate(VI); tarapacaite

**Uses**

Potassium chromate is used in enamels; rustproof metals; and leather finishes. The compound also is an indicator in argentometric titrations.

**Physical Properties**

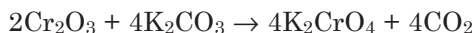
Lemon-yellow rhombohedral crystals; density 2.732 g/cm<sup>3</sup>; melts at 968°C; very soluble in water, 63 g/100mL at 20°C; aqueous solution alkaline; insoluble in alcohol.

**Thermochemical Properties**

|                    |                  |
|--------------------|------------------|
| $\Delta H_f^\circ$ | -335.5 kcal/mol  |
| $\Delta G_f^\circ$ | -309.7 kcal/mol  |
| $S^\circ$          | 47.8 cal/deg mol |
| $C_p$              | 34.9 cal/deg mol |

**Preparation**

Potassium chromate can be made from chrome ore (chromite, FeO • Cr<sub>2</sub>O<sub>3</sub>) that contains about 45% Cr<sub>2</sub>O<sub>3</sub>. The ore is crushed and mixed with potassium carbonate and roasted in air or oxygen at 1,100 to 1,250°C:



Potassium chromate also can be prepared by heating a mixture of pure potassium dichromate and potassium carbonate in a moist atmosphere. The salt is dried and purified by recrystallization.

Also, the compound may be obtained as an intermediate in the production of potassium dichromate. The product, however, contains trace amounts of potassium sulfate which is difficult to separate.

**Analysis**

Elemental composition: K 40.26%, Cr 26.78%, O 32.96%. An aqueous solution of the salt is analyzed for potassium and chromium (see Potassium and Chromium). Potassium chromate may be identified by its physical properties and by x-ray methods. Also, an aqueous solution of the salt forms a red precipitate of silver chromate when treated with a solution of silver nitrate. The chromate content may be determined stoichiometrically by weighing the dry precipitate.

**POTASSIUM CYANIDE**

[151-50-8]

Formula KCN; MW 65.12

**Uses**

Potassium cyanide is used in extracting gold, silver and platinum from

their ores. It also is used in electroplating baths and in making other cyanide salts and complexes.

### Physical Properties

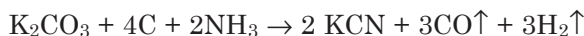
Colorless cubic crystals or white granular powder; deliquescent; density 1.52 g/cm<sup>3</sup>; melts at 634.5°C; readily dissolves in water, 50 g/100mL at 20°C, 100 g/100mL in boiling water; moderately soluble in methanol 4.9 g/100mL at 20°C; soluble in glycerol.

### Thermochemical Properties

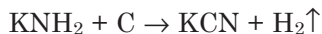
|                          |                   |
|--------------------------|-------------------|
| $\Delta H_f^\circ$ (cry) | -27.0 kcal/mol    |
| $\Delta H_f^\circ$ (gas) | 21.7 kcal/mol     |
| $\Delta G_f^\circ$ (cry) | -24.35 kcal/mol   |
| $\Delta G_f^\circ$ (gas) | 15.34 kcal/mol    |
| $S^\circ$ (cry)          | 30.71 cal/deg mol |
| $S^\circ$ (gas)          | 62.57 cal/deg mol |
| $C_r$ (cry)              | 15.84 cal/deg mol |
| $C_p$ (gas)              | 12.51 cal/deg mol |

### Preparation

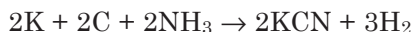
Potassium cyanide is prepared by heating a mixture of potassium carbonate and carbon with ammonia at high temperatures:



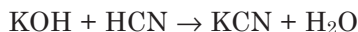
Also, potassium cyanide can be made by reduction of potassium amide with carbon at red heat:



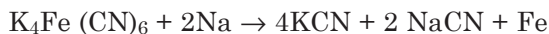
A preparative method similar to the Castner process for the production of sodium cyanide involves adding red-hot charcoal slowly to molten potassium in a steel vessel. The mixture is heated to about 750°C and then ammonia is introduced gradually. The fused product is pumped to a filter furnace at high temperature where the molten potassium cyanide is filtered in a nitrogen atmosphere. The overall reaction for the process is:



A convenient method of preparing potassium cyanide is to absorb hydrogen cyanide in 50% aqueous solution of potassium hydroxide followed by evaporation of the solution in a vacuum:



A mixture of sodium and potassium cyanides may be obtained by reduction of potassium ferrocyanide with sodium:



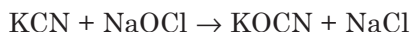
### Analysis

Elemental composition: K 60.05%, C 18.44%, N 21.51%. An aqueous solution of the salt is analyzed for potassium (see Potassium) and for  $\text{CN}^-$  by a cyanide ion-selective electrode. The solution must be diluted appropriately for measurement. Alternatively,  $\text{CN}^-$  may be titrated by the pyridine-barbituric acid colorimetric method (see Hydrogen Cyanide.)

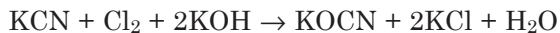
### Reactions

Reactions of potassium cyanide in aqueous solutions are essentially those of cyanide ion. A few reactions are highlighted below (molecular reactions are shown formally.)

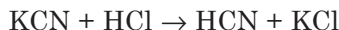
The salt in aqueous solution oxidizes to cyanate when treated with sodium hypochlorite:



Reaction with chlorine in alkaline medium also yields cyanate:



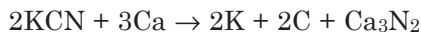
Reactions with acids liberate HCN:



Reactions with copper sulfate or copper chloride form cyanogen and metallic copper:



Potassium cyanide is reduced by powdered metals, such as calcium, magnesium, and aluminum when heated in the absence of air:



Potassium cyanide forms a number of complexes. For example, in aqueous solution it reacts with silver in the presence of air or oxygen to form a silver cyanide complex:



When an aqueous solution of potassium cyanide is boiled with sulfur, potassium thiocyanate is produced:



**Toxicity**

Potassium cyanide is a dangerously toxic substance. Ingestion of 100 to 150 mg can cause collapse and cessation of breathing in humans. At lower doses, the acute effects are nausea, vomiting, headache, confusion and muscle weakness (Patnaik, P.1999. *A Comprehensive Guide to the Hazardous Properties of Chemical Substances*, 2<sup>nd</sup> ed. pp. 292-294. New York: John Wiley & Sons). Contact with acid can liberate highly toxic vapors of hydrogen cyanide. Sodium thiosulfate and sodium sulfate have shown antidotal activity to KCN toxicity.

**Disposal and Destruction**

Small amounts of KCN or effluents containing cyanide can be destroyed by treatment with chlorine or hypochlorite in alkaline solution.

**POTASSIUM DICHROMATE**

[7778-50-9]

Formula:  $K_2Cr_2O_7$ ; MW 294.18

Synonyms: potassium bichromate; potassium dichromate(VI)

**Uses**

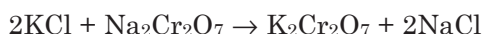
Potassium dichromate is a strong oxidizing agent. Many of its applications involve its oxidation action. The salt is used in pyrotechnics, safety matches, bleaching wax, palm oil, pigments, dyeing and painting, printing, photolithography, waterproofing fabrics, tanning leather, and inhibiting corrosion. Other uses are in electric batteries and as a depolarizer for dry cells. Potassium dichromate is an oxidizing agent in organic synthesis and in chromic cleaning mixture for laboratory glassware.

**Physical Properties**

Bright orange-red triclinic or monoclinic crystals; density 2.676 g/cm<sup>3</sup> at 25°C; triclinic form converts to monoclinic modification at 241.6°C; melts at 398°C; decomposes at 500°C; moderately soluble in cold water, 4.9 g/100mL at 0°C; very soluble in boiling water, 102 g/100mL at 100°C; aqueous solution acidic, a 10% solution has a pH 3.57; insoluble in alcohol.

**Preparation**

Potassium dichromate is obtained by reacting potassium chloride with sodium dichromate as a hot concentrated solution. The salt crystallizes when the solution is cooled:



As the least soluble of four salts,  $K_2Cr_2O_7$  crystallizes first from solution.

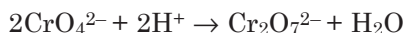


## 752 POTASSIUM FERRICYANIDE

Potassium dichromate also is produced from chrome ore. Ore is roasted with potassium carbonate or hydroxide to form potassium chromate:

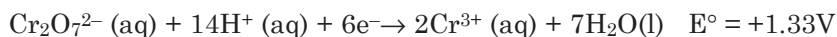


$\text{K}_2\text{CrO}_4$ , upon heating in air or oxygen, converts to dichromate. In acid solution at low pH, chromate ion converts to dichromate:

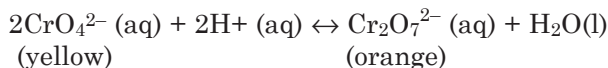


### Reactions

The dichromate ion,  $\text{Cr}_2\text{O}_7^{2-}$  is a strong oxidizing agent in acid solution:

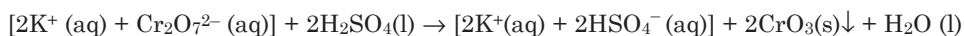


The yellow solution of chromate salt on acidification turns orange due to formation of dichromate ion. Both the ions are in equilibrium, sensitive to pH change:

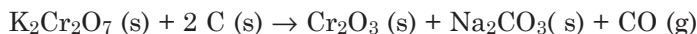


In aqueous solution, it undergoes many redox reactions. Some of these reactions are similar to those of permanganate ion;  $\text{MnO}_4^-$ .

When concentrated sulfuric acid is added, it precipitates red crystalline chromium(VI) oxide,  $\text{CrO}_3$ :



When heated with carbon, potassium dichromate converts to chromium(III) oxide:



### Analysis

Elemental composition: K 26.58%, Cr 35.36%, and O 38.07%. Diluted aqueous solution is analyzed for the metals potassium and chromium (see Potassium and Chromium). Also, the salt can be identified from its color and other physical properties.

## POTASSIUM FERRICYANIDE

[13746–66–2]

Formula:  $\text{K}_3\text{Fe}(\text{CN})_6$ ; MW 329.25

Synonyms: potassium hexacyanoferrate(III); tripotassium hexakis(cyano-C)ferrate(3–); red prussiate of potash

### Uses

Potassium ferricyanide is used to make pigments, as a coloring agent for blueprints, in calico printing, for dyeing wool, for staining wood, and as an etching liquid. It also is used in electroplating and for tempering iron and steel. The compound also is a mild oxidizing agent and finds limited use in preparing certain organics. In analytical chemistry it is used for standardization of sodium thiosulfate solution.

### Physical Properties

Bright red lustrous crystals; density 1.89 g/cm<sup>3</sup>; decomposes on heating; soluble in water, ~40 g/100mL at 20°C ; decomposes slowly on standing; slightly soluble in alcohol; soluble in acids with decomposition

### Preparation

Potassium ferricyanide is prepared by oxidation of potassium ferrocyanide, K<sub>4</sub>Fe(CN)<sub>6</sub>. Thus, when chlorine is passed through an aqueous solution of potassium ferrocyanide, the ferricyanide separates as crystals.

### Analysis

Elemental composition: K 35.62%, Fe 16.96%, C 21.89%, N 25.53%. An aqueous solution of the salt may be analyzed for potassium and iron by various instrumental methods (see Iron, and Potassium Analysis). Its concentration in aqueous solution may be measured by adding excess potassium iodide to an acidified solution and titrating the iodine liberated with a standard solution of sodium thiosulfate using starch indicator.

## POTASSIUM FERROCYANIDE

[13943-58-3]

Formula: K<sub>4</sub>Fe(CN)<sub>6</sub>; MW 368.34; exists as trihydrate, K<sub>4</sub>Fe(CN)<sub>6</sub>·3H<sub>2</sub>O [14459-95-1] having a molecular weight 422.39

Synonyms: potassium hexacyanoferrate(II); tetrapotassium hexakis(cyano-C)ferrate(4-); yellow prussiate of potash

### Physical Properties

The trihydrate is a yellow monoclinic crystalline complex salt; density 1.85 g/cm<sup>3</sup>; begins to lose water at 60°C; becomes anhydrous at 100°C; soluble in water, insoluble in ethanol and ether

### Preparation

Potassium ferrocyanide may be prepared by the action of potassium cyanide with ferrous sulfate solution:



The complex also may be obtained by reduction of potassium ferricyanide,  $K_3Fe(CN)_6$ , with a suitable reducing agent, such as sodium oxalate,  $Na_2C_2O_4$ , or sodium thiosulfate,  $Na_2S_2O_3$ .

### Analysis

Elemental composition: K 42.46%, Fe 15.16%, C 19.56%, N 22.82%. An aqueous solution may be analyzed for potassium and iron by various instrumental means (see Potassium and Iron, Analysis).

## POTASSIUM FLUORIDE

[7789-23-3]

Formula KF; MW 58.10

### Uses

Potassium fluoride is a fluorinating agent in organic synthesis. Other applications are in making insecticide formulations, as an additive to flux for making hard solder, and to control fermentation.

### Physical Properties

Colorless cubic crystals or white deliquesce powder or solid; density 2.48 g/cm<sup>3</sup>; melts at 858°C; vaporizes at 1,505°C; soluble in water, 92 g/100mL at 18°C, very soluble in hot water; soluble in hydrofluoric acid; insoluble in alcohol.

### Thermochemical Properties

|                    |                  |
|--------------------|------------------|
| $\Delta H_f^\circ$ | -135.6 kcal/mol  |
| $\Delta G_f^\circ$ | -128.5 kcal/mol  |
| $S^\circ$          | 15.9 cal/deg mol |
| $C_p$              | 11.7 cal/deg mol |

### Preparation

Potassium fluoride is prepared by dissolving potassium carbonate in excess hydrofluoric acid. Evaporation of the solution forms crystals of potassium bifluoride. The bifluoride on heating yields potassium fluoride:



The salt must not be prepared in glass or porcelain vessels as HF and the aqueous solution of KF corrode glass and porcelain. Heat resistant plastic containers may be used.

**Analysis**

Elemental composition: K 67.30%, F 32.70%. The aqueous solution may be analyzed for potassium by various methods (see Potassium.) and for fluoride by fluoride ion selective electrodes or ion chromatography.

**Toxicity**

Potassium fluoride is moderately toxic by ingestion. The oral LD<sub>50</sub> in guinea pigs is 250 mg/kg.

**POTASSIUM FORMATE**

[590–29–4]

Formula: HCOOK; MW 84.12

**Use**

Potassium formate is used to prepare potassium oxalate simply by heating at 360°C.

**Physical Properties**

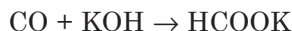
Colorless rhombohedral crystals or deliquesce granules; density 1.91 g/cm<sup>3</sup>; melts at 167.5°C; decomposes on further heating; highly soluble in water, 331 g/100mL at 18°C, much greater solubility in hot water, 657 g/100mL at 80°C; soluble in alcohol; insoluble in ether.

**Thermochemical Properties**

$$\Delta H_f^\circ \quad -126.5 \text{ kcal/mol}$$

**Preparation**

Potassium formate is produced slowly by absorption of carbon monoxide by 50 to 80 wt% aqueous solution of potassium hydroxide at 100 to 200°C and a CO partial pressure over 7 atm.



Potassium formate also can be made by passing pure carbon monoxide or purified producer gas (sometimes called blow gas) containing about 30% carbon monoxide under pressure through a hot solution of potassium sulfate and milk of lime:



The solution is filtered to remove calcium sulfate.

**Analysis**

Elemental composition: K 46.48%, C 14.28%, H 1.20%, O 38.04%. The aqueous solution is analyzed for potassium by various methods (see Potassium). The salt is heated at 360°C and converted to oxalate. The oxalate formed may be dissolved in water and the solution may be measured quantitatively for oxalate by redox titration.

**POTASSIUM HYDRIDE**

[7693–26–7]

Formula: KH; MW 40.11

**Uses**

Potassium hydride is a reducing agent.

**Physical Properties**

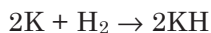
White needle; density 1.47 g/cm<sup>3</sup>; decomposes to its elements on heating; reacts violently with water, evolving hydrogen; insoluble in benzene, ether, and carbon disulfide.

**Thermochemical Properties**

$\Delta H_f^\circ$                       -13.80 kcal/mol

**Preparation**

Potassium hydride is prepared by passing hydrogen over potassium at high temperature:



Alternatively, the hydride may be made by passing hydrogen into molten potassium dispersed in oil.

**Analysis**

Elemental composition: K 97.48%, H 2.52%. The hydride may be decomposed cautiously in water in small amounts (the reaction is violent) and the solution analyzed for potassium (see Potassium). Hydrogen may be identified by its combustion (see Hydrogen).

**POTASSIUM HYDROGEN PHTHALATE**

[877–24–7]

Formula: C<sub>8</sub>H<sub>5</sub>KO<sub>4</sub>; MW 204.22;

Structure: HOOC-C<sub>6</sub>H<sub>4</sub>-COOK

Synonyms: potassium biphthalate; potassium acid phthalate; acid potassium phthalate; phthalic acid potassium acid salt; KHP

## Uses

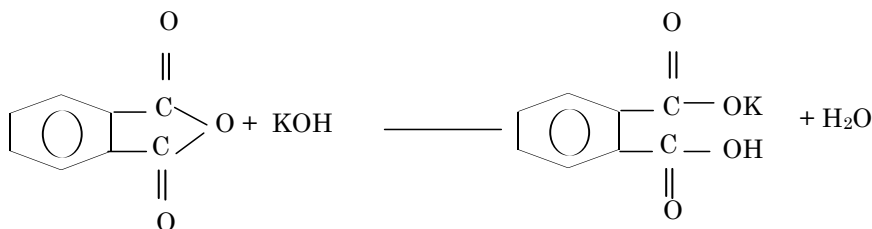
Potassium hydrogen phthalate has many uses in analytical chemistry. It is a primary standard for standardization of bases in aqueous solutions. Its equivalent weight is 204.2. It also is a primary standard for acids in anhydrous acetic acid. Other applications are as a buffer in pH determinations and as a reference standard for chemical oxygen demand (COD). The theoretical COD of a 1mg/L potassium hydrogen phthalate is 1.176mg O<sub>2</sub>.

## Physical Properties

White orthorhombic crystals; stable in air; density 1.636 g/cm<sup>3</sup> at 25°C; soluble in water, about 8.3g /100mL at 20°C and 33 g/100mL in boiling water; pH of 0.05M aqueous solution 4.005 at 25°C; slightly soluble in ethanol.

## Preparation

Potassium hydrogen phthalate is prepared by neutralization reaction of phthalic anhydride and potassium hydroxide, followed by crystallization:

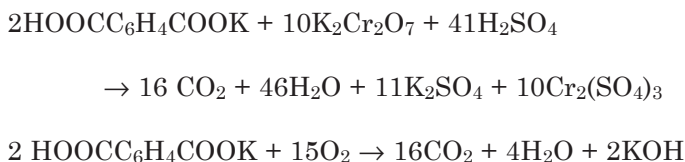


Alternatively, it is prepared by half neutralization of phthalic acid with potassium hydroxide:



## Reactions

Aqueous solutions of potassium hydrogen phthalate, when refluxed with a powerful oxidizing agent such as potassium dichromate–sulfuric acid mixture, completely decompose, forming various products. Under closed refluxing conditions, K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> provides all the oxygen required for the oxidation. (Patnaik, P 1997. *Handbook of Environmental Analysis*, pp.197. Boca Raton, FL: CRC Press) The reactions under closed and open refluxing conditions are:



Potassium hydrogen phthalate undergoes neutralization with alkalies:



The theoretical COD for 100 mg phthalate is 117.5 mg O<sub>2</sub>

### Analysis

Elemental composition: K 30.51%, C18.75%, H 0.79%; O 49.95%. An aqueous solution of potassium hydrogen phthalate may be measured by titration against a standard solution of potassium hydroxide.

## POTASSIUM HYDROXIDE

[1310-58-3]

Formula KOH; MW 56.11

Synonyms: caustic potash; potassa; potassium hydrate

### Uses

Potassium hydroxide is used to make soft soap, in scrubbing and cleaning operations, as a mordant for woods, in dyes and colorants, and for absorbing carbon dioxide. Other principle uses of caustic potash are in the preparation of several potassium salts, acid-base titrations, and in organic syntheses. Also, KOH is an electrolyte in certain alkaline storage batteries and fuel cells.

### Physical Properties

White rhombohedral deliquescent crystal; density 2.044 g/cm<sup>3</sup>; melts at 360°C; vaporizes around 1,320°C; highly soluble in water, 107 g/100mL at 15°C and 178 g/100mL at 100°C; aqueous solution highly alkaline, pH of 0.1M solution is 13.5; soluble in alcohol and glycerol; insoluble in ether and liquid ammonia.

### Thermochemical Properties

|                          |                   |
|--------------------------|-------------------|
| $\Delta H_f^\circ$       | -101.52 kcal/mol  |
| $\Delta G_f^\circ$       | -90.61 kcal/mol   |
| $S^\circ$                | 15.51 cal/deg mol |
| $C_p$                    | 18.85 cal/deg mol |
| $\Delta H_{\text{soln}}$ | -13.8 kcal/mol    |

### Production

Potassium hydroxide is produced commercially by electrolysis of a saturated solution of potassium chloride in brine using mercury cells consisting of a titanium anode and mercury cathode. Potassium reacts with mercury forming the amalgam which, on treatment with water, forms potassium hydroxide and hydrogen.

Other types of electrolytic cells, although not so commonly used today, are also known. In a diaphragm type cell that separates the cell into anode and cathode compartments, an aqueous solution of potassium chloride is electrolyzed. Potassium hydroxide and hydrogen are produced at the cathode and chlorine is liberated at the anode. The solution discharged from the cell is

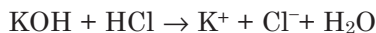
evaporated to concentrate potassium hydroxide and precipitate potassium chloride.

Potassium hydroxide also may be made by reacting potassium superoxide with water:



### Reactions

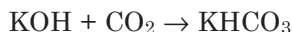
Potassium hydroxide is a very strong base, more basic than caustic soda. It is neutralized by acids. The solution on evaporation yields the corresponding potassium salt:



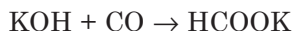
Action of bromine or iodine on a warm concentrated solution of KOH forms bromate and bromide or iodate and iodide, respectively:



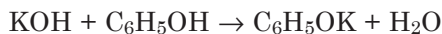
When carbon dioxide is passed through its aqueous solution and the solution evaporated, potassium bicarbonate is formed:



Reaction with carbon monoxide at 100 to 200°C at a CO pressure above 7 atm yields potassium formate:



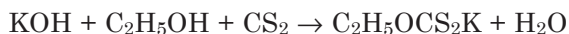
Reaction with phenol in dilute methanol solution forms potassium phenoxide:



Reaction with boric acid and hydrofluoric acid forms potassium tetrafluoroborate,  $\text{KBF}_4$ :

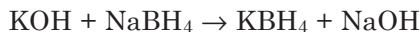


An alcoholic solution of potassium hydroxide reacts with an alcoholic solution of carbon disulfide to form potassium ethylxanthogenate,  $\text{C}_2\text{H}_5\text{OCS}_2\text{K}$

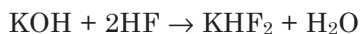


Reaction with sodium borohydride forms potassium borohydride:





Reaction with hydrofluoric acid forms potassium bifluoride:



Half neutralization of a phthalic anhydride solution forms potassium hydrogen phthalate.

### Analysis

The normality of KOH in its aqueous solution can be determined by acid-base titration against a standard solution of HCl, H<sub>2</sub>SO<sub>4</sub>, or HNO<sub>3</sub> using a color indicator or by a pH meter. Potassium can be identified by flame test or by wet methods or instrumental analysis (see Potassium).

## POTASSIUM IODATE

[7758-05-6]

Formula: KIO<sub>3</sub>; MW 214.00

### Uses

Potassium iodate is an oxidizing agent in volumetric analysis. It releases iodine in KIO<sub>3</sub>–KI solutions for iodometric titrations. It also is a topical anti-septic; and an additive to food to provide nutrient iodine.

### Physical Properties

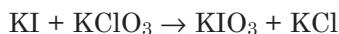
Colorless crystals or white powder; monoclinic structure; density 3.90 g/cm<sup>3</sup>; stable at ordinary temperatures; melts at 560°C with partial decomposition, releasing oxygen; moderately soluble in cold water; 4.74 g/100mL at 0°C; greater solubility in boiling water 32.3 g/100mL at 100°C; soluble in potassium iodide solution; insoluble in alcohol and liquid ammonia

### Thermochemical Properties

|                    |                  |
|--------------------|------------------|
| $\Delta H_f^\circ$ | –119.8 kcal/mol  |
| $\Delta G_f^\circ$ | –100.0 kcal/mol  |
| $S^\circ$          | 36.2 cal/deg mol |
| $C_p$              | 25.4 cal/deg mol |

### Preparation

Potassium iodate can be produced by fusing potassium iodide with potassium chlorate, bromate or perchlorate:



The melt is extracted with water and potassium iodate is isolated from solu-

tion by crystallization.

### Analysis

Elemental composition: K 18.27%, I 59.30%, and O 22.43%. An aqueous solution may be analyzed for potassium (see Potassium) and for  $\text{IO}_3^-$  by ion chromatography. The iodate,  $\text{IO}_3^-$  content can be measured by iodometric titration:



In strong acid solution  $\text{IO}_3^-$  oxidizes  $\text{I}^-$  liberating iodine, which can be titrated against a standard solution of sodium thiosulfate. At the end point, the blue solution decolorizes.

## POTASSIUM IODIDE

[7681-11-0]

Formula: KI; MW 166.00

### Occurrence and Uses

Potassium iodide is found in seaweed. Some important applications of this compound involve its use in pharmaceuticals and as a source of iodine in food, especially in animal and poultry feed. Potassium iodide is added to table salt to provide iodine in human food.

Another major use is in making photographic emulsions. In analytical chemistry, potassium iodide is used in iodometric titration with starch indicator to analyze dissolved oxygen, dissolved chlorine, sulfide, and other analytes in water.

### Physical Properties

Colorless or white cubic crystals or granules; becomes yellowish when exposed to bright light due to photochemical decomposition liberating traces of free iodine; density 3.13 g/cm<sup>3</sup>; melts at 681°C; vaporizes at 1,330°C; highly soluble in water, ~140 g/100mL at 20°C; aqueous solution readily dissolves iodine; sparingly soluble in ethanol (about 2 g/100mL at 25°C) and acetone; slightly soluble in ether and ammonia.

### Thermochemical Properties

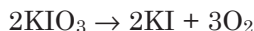
|                    |                   |
|--------------------|-------------------|
| $\Delta H_f^\circ$ | -78.37 kcal/mol   |
| $\Delta G_f^\circ$ | -77.65 kcal/mol   |
| $S^\circ$          | 25.4 cal/deg mol  |
| $C_p$              | 12.65 cal/deg mol |

### Preparation

Potassium iodide is made by absorption of iodine in potassium hydroxide:



Most potassium iodate,  $\text{KIO}_3$ , is separated from the product mixture by crystallization and filtration. Remaining iodates are removed by evaporation of the solution and other processes, such as carbon reduction or thermal decomposition at  $600^\circ\text{C}$  to iodide:

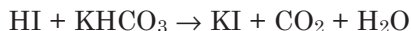


Another method of preparation that does not involve the formation of iodate is by treating iron turnings with iodine solution. The product, ferrous-ferrous ferric iodide,  $\text{Fe}_3\text{I}_8 \cdot 16\text{H}_2\text{O}$ , is boiled with 15 wt% potassium carbonate solution:



A similar method is used to prepare potassium bromide, discussed earlier (see Potassium Bromide.)

Potassium iodide can be prepared by reacting hydriodic acid with potassium bicarbonate:



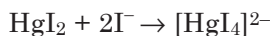
It is purified by melting in dry hydrogen.

Potassium iodide also may be obtained by various electrolytic processes.

### Reactions

The reactions of potassium iodide in aqueous solutions are those of iodide ion,  $\text{I}^-$ . In iodometric titration  $\text{I}^-$  combines with iodine to form triiodide ion,  $\text{I}_3^-$ . The latter adds to  $\beta$ -amylose fraction of the starch to form a blue complex.

Potassium iodide dissolves iodide of certain metals to form complex anions:



### Analysis

Elemental composition: K 23.55%, I 76.45%. Potassium may be measured by various instrumental methods (see Potassium). Iodide ion in an aqueous solution can be measured by ion chromatography or leuco crystal violet colorimetric method (see Iodine).

## POTASSIUM NITRATE

[7757-79-1]

Formula  $\text{KNO}_3$ ; MW 101.10

Synonyms: saltpeter; niter

## Uses

Potassium nitrate is used in explosives, blasting powders, gunpowder, matches, and fireworks. Other applications of this salt include pickling meats; tempering steel; impregnating candle wicks; freezing mixtures; preparing other potassium salts; and as a diuretic.

## Physical Properties

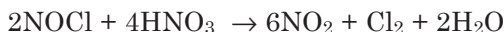
Colorless transparent crystals or white granular or crystalline powder; rhombohedral structure; density 2.11 g/cm<sup>3</sup> at 20°C; melts at 334°C; decomposes at 400°C evolving oxygen; soluble in cold water, 13.3 g/100mL at 0°C; highly soluble in boiling water, 247 g/100mL at 100°C; lowers the temperature of water on dissolution; very slightly soluble in ethanol; soluble in glycerol and liquid ammonia.

## Thermochemical Properties

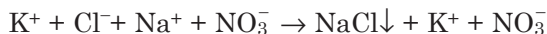
|                    |                   |
|--------------------|-------------------|
| $\Delta H_f^\circ$ | -118.22 kcal/mol  |
| $\Delta G_f^\circ$ | -94.39 kcal/mol   |
| $C_p$              | 31.80 cal/deg mol |
| $S^\circ$          | 23.04 cal/deg mol |

## Production

Potassium nitrate may be produced by several methods. It is made commercially by reacting potassium chloride with nitric acid at high temperature. Nitrosyl chloride, a product obtained in the reaction, is converted into chlorine in this manufacturing process. Also, nitric acid is partly recycled in the process. The reactions are (Dancy, W.B. 1981. Potassium Compounds. In *Kirk-Othmer Encyclopedia of Chemical Technology*, 3<sup>rd</sup>. ed. Pp. 939-42. New York: Wiley Interscience):



Potassium nitrate also can be prepared by mixing a hot saturated solution of potassium chloride and sodium nitrate. The reaction is:



Sodium chloride is less soluble than KCl, NaNO<sub>3</sub> and KNO<sub>3</sub>. It separates out by crystallization. The remaining solution is cooled to ambient temperature. Potassium nitrate crystallizes out.

## Analysis

The aqueous solution may be analyzed for potassium by various instru-

mental and wet methods (see Potassium) and for nitrate ion by ion chromatography or electrode method.

## POTASSIUM NITRITE

[7758-09-0]

Formula:  $\text{KNO}_2$ ; MW 85.10

### Uses

Potassium nitrite is an antidote to cyanide poisoning. It also is a vasodilator. An important application is in the dye industry to prepare diazonium salts and azo dyes. Another use is in curing certain meat products where the salt imparts an appetizing pink color to cured meats and retards microbial growth on the meat. The commercial product is usually a nitrite-nitrate mixture, containing 85%  $\text{KNO}_2$  and 15%  $\text{KNO}_3$ .

### Physical Properties

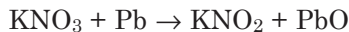
White or slight yellow prismatic granules; deliquesce; density 1.915 g/cm<sup>3</sup>; melts at 440°C; decomposition starts at 350°C; very soluble in water, 281 g/100mL at 0°C; much more soluble in boiling water, 413 g/100mL at 100°C; aqueous solution is alkaline; slightly soluble in cold alcohol but moderately soluble in hot alcohol; very soluble in liquid ammonia; decomposes in acids, liberating brown  $\text{NO}_2$  fumes.

### Thermochemical Properties

|                    |                   |
|--------------------|-------------------|
| $\Delta H_f^\circ$ | -88.39 kcal/mol   |
| $\Delta G_f^\circ$ | -73.28 kcal/mol   |
| $S^\circ$          | 36.35 cal/deg mol |
| $C_p$              | 25.67 cal/deg mol |

### Preparation

Potassium nitrite may be prepared by fusion of nitrate with lead:



The product is extracted with water and allowed to crystallize. Filtration separates nitrite from insoluble lead oxide.

Potassium nitrite also may be obtained by high temperature thermal decomposition of nitrate:



### Analysis

Elemental composition: K 45.94%, N 16.46%, O 37.60%. An aqueous solution of the salt may be analyzed for potassium (see Potassium). The nitrite ion may be measured by colorimetric methods. The  $\text{NO}_2^-$  is diazotized with sul-

fanilamide and coupled with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye. The absorbance or transmittance of the solution can be measured at 543 nm or 540 nm using a spectrophotometer or a filter photometer. Nitrite anion in the presence of nitrate can be best measured by ion chromatography using a low capacity strongly basic anion exchange separator column.

## POTASSIUM OXALATE

[127–96–8]

Formula  $K_2C_2O_4$ ; MW 166.22; forms a stable monohydrate,  $K_2C_2O_4 \cdot H_2O$ , MW 184.23 [6487–48–5]

### Occurrence and Uses

Potassium oxalate, along with calcium oxalate, is found in leaves and roots of certain plants. It is used for cleaning and bleaching straw and for removing stains. It also is used in photography, in clinical tests, as a secondary pH standard, and in wet chemical analysis. The analytical application involves standardization of many oxidizing agents in titrimetric analysis.

### Physical Properties

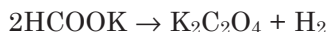
The monohydrate is a white crystalline solid; monoclinic structure; density 2.13 g/cm<sup>3</sup>; loses its water at about 160°C; converts to carbonate when ignited; effloresces in warm dry air; soluble in water, 33 g/100 mL at 20°C; a 0.05M solution of  $K_2C_2O_4 \cdot 2H_2O$  has a pH 1.679.

### Thermochemical Properties

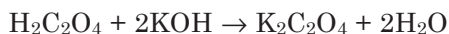
$$\Delta H_f^\circ \quad -321.9 \text{ kcal/mol}$$

### Preparation

Potassium oxalate can be prepared by heating potassium formate at 360°C:



The salt is obtained as its monohydrate by neutralization of oxalic acid with a dilute aqueous solution of potassium hydroxide followed by crystallization:



### Analysis

Elemental composition (for anhydrous  $K_2C_2O_4$ ): K 47.05%, C 14.45%, O 38.50%. The water content of the monohydrate,  $K_2C_2O_4 \cdot H_2O$  is 9.78%, which may be measured by thermogravimetric analysis. Potassium may be analyzed by AA, flame photometry or ICP/AES (see Potassium). The concentration of oxalate in the aqueous solution of the salt may be determined by titrating

against a standard solution of potassium bromate in the presence of excess potassium bromide.

### Toxicity

Ingestion can cause irritation of the GI tract, shock and cardiac arrhythmias.

## POTASSIUM PERCARBONATE

[589–97–9]

Formula  $K_2C_2O_6$ ; MW 198.22; stable as a monohydrate,  $K_2C_2O_6 \cdot H_2O$ ; MW 216.23

Synonyms: potassium peroxydicarbonate; potassium perdicarbonate; peroxydicarbonic acid dipotassium salt.

### Uses

Potassium percarbonate is used in photography under the name “Anti-hypo” for removing the last traces of thiosulfate from film and paper. It is a strong oxidizing agent in certain chemical analysis; and in microscopic identification of *tubercle bacilli*.

### Physical Properties

The monohydrate consists of a white granular mass; starts melting above 200°C; soluble in water, about 15 g/100mL at 20°C; decomposes in boiling water, evolving oxygen.

### Preparation

Potassium percarbonate can be prepared by electrolysis of potassium carbonate,  $K_2CO_3$ .

### Analysis

Elemental composition: K 39.45%, C 12.12%, O 48.43%. An aqueous solution is analyzed for potassium. The solution is boiled and evolved oxygen is identified by its inflaming a glowing splinter. Also, evolved oxygen may be introduced into a stream of carrier gas, helium, and analyzed by GC or GC/MS. The characteristic mass for its identification by GC/MS is 32.

## POTASSIUM PERCHLORATE

[7778–74–7]

Formula  $KClO_4$ ; MW 138.55

Synonym: peroidin

### Uses

Potassium perchlorate is used in explosives and pyrotechnics. It also is used in photography.

### Physical Properties

Colorless crystals or white crystalline powder; rhombohedral structure; density 2.52 g/cm<sup>3</sup>; melts around 610°C under controlled conditions; decomposes at 400°C; slightly soluble in cold water 0.75 g/100mL at 0°C, soluble in boiling water, 21.8 g/100mL at 100°C; practically insoluble in alcohol; insoluble in ether.

### Thermochemical Properties

|                    |                  |
|--------------------|------------------|
| $\Delta H_f^\circ$ | -103.43 kcal/mol |
| $\Delta G_f^\circ$ | -72.46 kcal/mol  |
| $S^\circ$          | 36.1 cal/deg mol |
| $C_p$              | 26.9 cal/deg mol |

### Preparation

Potassium perchlorate is prepared from potassium chlorate. Potassium chlorate, on heating, melts first and then resolidifies to potassium perchlorate:

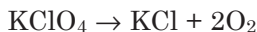


Potassium perchlorate is produced commercially by electrolysis of a saturated solution of potassium chlorate. Hydrogen gas is liberated at the cathode. The reaction at the anode is:

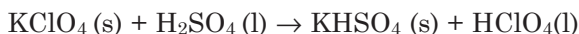


### Reactions

On strong heating, potassium perchlorate decomposes to potassium chloride and oxygen:



The salt, on treatment with sulfuric acid, yields potassium bisulfate and perchloric acid:



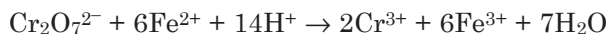
In aqueous solution the reactions of potassium perchlorate are those of the  $\text{ClO}_4^-$  ion.

It is an oxidizing agent and undergoes redox reactions with reducing agents. Its oxidizing action, however, is weaker to that of potassium chlorate. Thus the salt is unable to oxidize the iodide ion to iodine in acid medium.



**Analysis**

Elemental composition: K 28.22%, Cl 25.59%, and O 46.19%. An aqueous solution is analyzed for potassium by AA, ICP, and other methods (see Potassium). Perchlorate ion may be analyzed by ion chromatography or a liquid-membrane electrode. Iodide, bromide, chlorate, and cyanide ions interfere in the electrode measurement. Alternatively, perchlorate ion may be measured by redox titration. Its solution in 0.5M H<sub>2</sub>SO<sub>4</sub> is treated with a measured excess standard ferrous ammonium sulfate. The excess iron(II) solution is immediately titrated with a standard solution of potassium dichromate. Diphenylamine sulfuric acid may be used as an indicator to detect the end point:

**POTASSIUM PERIODATE**

[7790-21-8]

Formula: KIO<sub>4</sub>; MW 230.00

Synonym: potassium metaperiodate

**Uses**

Potassium periodate is a powerful oxidizing agent in acid. It is, therefore, used as an oxidizing agent in organic synthesis and in titrimetric and colorimetric analysis based on its oxidation-reduction reactions.

**Physical Properties**

Colorless tetragonal crystals; density 3.618 g/cm<sup>3</sup>; melts at 582°C; slightly soluble in water at ordinary temperatures, 0.42 g/100mL at 20°C; moderately soluble in hot water, 4.4 g/100mL at 80°C.

**Thermochemical Properties**

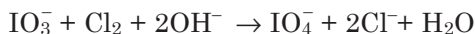
$$\Delta H_f^\circ \quad -111.7 \text{ kcal/mol}$$

$$\Delta G_f^\circ \quad -86.4 \text{ kcal/mol}$$

$$S^\circ \quad 42.0 \text{ cal/deg mol}$$

**Preparation**

Potassium periodate can be prepared by oxidation of potassium iodate with a powerful oxidizing agent such as potassium permanganate, chlorine or bromine in basic solution:



Also, the salt may be prepared by electrolysis.

**Analysis**

Elemental composition: K 17.00, I 55.18%, and O 27.82%. An aqueous solu-

tion of potassium periodate is analyzed for potassium by AA, ICP, and other methods (see Potassium) and for periodate ion by ion chromatography. Alternatively, the solution is buffered with sodium bicarbonate, made slightly alkaline, and then treated with excess potassium iodide. The liberated iodine is titrated with a standard solution of sodium thiosulfate or sodium arsenite using starch indicator.

## POTASSIUM PERMANGANATE

[7722-64-7]

Formula:  $\text{KMnO}_4$ ; MW 158.03

Synonyms: permanganic acid potassium salt; chameleon mineral

### Uses

Potassium permanganate is widely used as an oxidizing agent in analytical chemistry and in organic synthesis. The salt is a disinfectant in water purification. Other important applications are in bleaching a variety of materials including cotton, silk, and other fibers, fats, oils, resins, and waxes. Miscellaneous applications are in printing fabrics, tanning leathers, and photography.

### Physical Properties

Dark purple rhombohedral crystal; density  $2.703 \text{ g/cm}^3$ ; stable in air; decomposes at about  $240^\circ\text{C}$ ; moderately soluble in cold water,  $6.38 \text{ g/100mL}$  at  $20^\circ\text{C}$ , soluble in hot water,  $25 \text{ g/100mL}$  at  $65^\circ\text{C}$ ; decomposed by alcohol, acetone and many organic solvents causing their oxidation; also decomposed by concentrated acids.

### Thermochemical Properties

|                    |                            |
|--------------------|----------------------------|
| $\Delta H_f^\circ$ | $-200.1 \text{ kcal/mol}$  |
| $\Delta G_f^\circ$ | $-176.3 \text{ kcal/mol}$  |
| $S^\circ$          | $41.0 \text{ cal/deg mol}$ |
| $C_p$              | $28.1 \text{ cal/deg mol}$ |

### Reactions

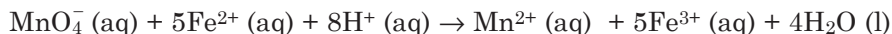
Potassium permanganate is a powerful oxidizing agent. In acid medium its oxidizing ability may be attributed to its high redox potential  $E^\circ$  which is  $+1.51 \text{ V}$  for the reaction:



In basic solution, the redox potential for the half reaction,  $\text{MnO}_4^- + 2\text{H}_2\text{O} + 3\text{e}^- \rightarrow \text{MnO}_2 + 4\text{OH}^-$ , is  $+0.60\text{V}$ .

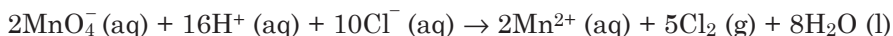
All reactions of potassium permanganate in aqueous solutions are essentially those of the  $\text{MnO}_4^-$  ion. Some examples are:

In acid solution it readily oxidizes  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$ :

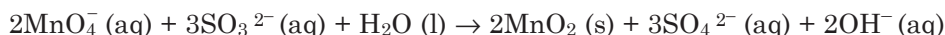


The purple color of  $\text{MnO}_4^-$  disappears when it is reduced to  $\text{Mn}^{2+}$ .

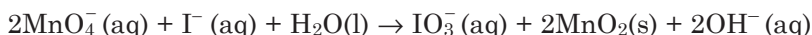
Permanganate ion oxidizes chloride ion in acid solution to chlorine gas. The net ionic equation is:



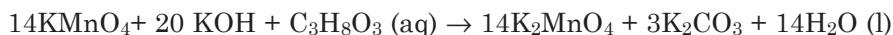
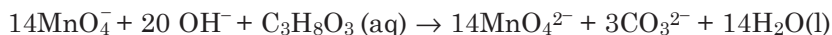
In basic solution  $\text{MnO}_4^-$  oxidizes sulfide to sulfate:



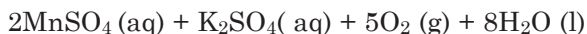
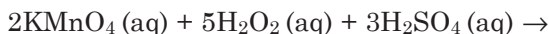
and iodide to iodate:



In basic solution,  $\text{MnO}_4^-$  oxidizes glycerol to carbonate. The net ionic equation and formal molecular reaction are:



Potassium permanganate reacts with hydrogen peroxide in dilute sulfuric acid to form manganous sulfate, potassium sulfate, and evolving oxygen. A molecular equation for this reaction is:

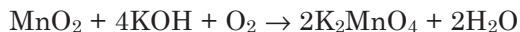


Potassium permanganate oxidizes oxalic acid evolving carbon dioxide. This reaction is often used to standardize  $\text{KMnO}_4$  solutions. A molecular equation is:



### Preparation

Potassium permanganate is produced from manganese ore containing at least 60% manganese dioxide,  $\text{MnO}_2$ . The finely ground ore is mixed with 50% potassium hydroxide and heated at about  $350^\circ\text{C}$  in rotary kilns. This converts manganese dioxide to potassium manganate:



Potassium manganate obtained above is oxidized to the permanganate either by electrolysis or by chemical oxidation. Electrolytic oxidation is more common. Electrolytic cells have cathodes made of iron rods and nickel-plated anodes. Potassium manganate melt is extracted with water prior to its electrolysis and then electrolyzed at a cell voltage of 2.3V and current of about 1,400 amp. Permanganate is produced at the anode and water is reduced to gaseous hydrogen and hydroxyl ions at the cathode:



### Analysis

Elemental composition: K 24.74%, Mn 34.76%, O 40.50%. The compound may be identified by its dark purple color and other physical properties, and confirmed by chemical analysis for the elements potassium and manganese by AA, ICP, and other instrumental means (see Potassium and Manganese). The concentration of permanganate ion,  $\text{MnO}_4^-$  in aqueous solution may be determined by titration with a standard solution of oxalic acid or ferrous ion (see Reactions).

## POTASSIUM PERSULFATE

[7727-21-1]

Formula:  $\text{K}_2\text{S}_2\text{O}_8$ ; MW 270.31

Synonyms: potassium peroxydisulfate; potassium perdisulfate; peroxydisulfuric acid dipotassium salt; Anthion (in photography)

### Uses

Potassium persulfate is an oxidizing agent in analytical chemistry, used in the measurement of organic phosphorus in wastewaters. Some important applications are in bleaching fabrics; removal of last traces of thiosulfate from photographic negatives and paper; oxidizing certain dyes in cotton printing; and initiating copolymerization reactions.

### Physical Properties

Colorless or white crystals; triclinic structure; density 2.477 g/cm<sup>3</sup>; stable in solid crystalline form; decomposes on heating, evolving oxygen; completely decomposes at about 100°C; sparingly soluble in cold water 1.75 g/100mL at 0°C; moderately soluble at ordinary temperature, 5.29 g/100 mL at 20°C; aqueous solution acidic and unstable, decomposing slowly at room temperature and more rapidly when the solution is warmed; insoluble in alcohol.

### Preparation

Potassium persulfate can be prepared by electrolysis of a mixture of potassium sulfate and potassium hydrogen sulfate at a high current density:

## 772 POTASSIUM PHOSPHATE, DIBASIC AND MONOBASIC



Also, the compound can be prepared by adding potassium hydrogen sulfate, KHSO to an electrolyzed solution of ammonium hydrogen sulfate,  $\text{NH}_4\text{HSO}_4$

### POTASSIUM PHOSPHATE, DIBASIC

[7758-11-4]

Formula:  $\text{K}_2\text{HPO}_4$ ; MW 174.18

Synonyms: dipotassium hydrogen phosphate; dipotassium phosphate; potassium hydrogen phosphate.

#### Uses

The salt is a buffering agent in antifreeze solutions. Other applications are in fertilizers; nondairy creams; and culturing of antibiotics.

#### Physical Properties

White amorphous powder; deliquesces; decomposes on heating; converts to pyrophosphate when ignited; very soluble in water, 167 g/100mL at 20°C; very soluble in alcohol; aqueous solution slightly alkaline.

#### Preparation

Dipotassium phosphate is prepared by partial neutralization of phosphoric acid with potassium hydroxide, followed by crystallization:



#### Analysis

Elemental composition: K 44.89%, P 17.79%, H 0.58%, and O 36.74%. An aqueous solution may be analyzed for potassium by various methods (see Potassium) and for phosphorus by colorimetry (see Phosphorus).

### POTASSIUM PHOSPHATE, MONOBASIC

[7778-77-0]

Formula:  $\text{KH}_2\text{PO}_4$ ; MW 136.09

Synonyms: potassium dihydrogen phosphate; potassium biphosphate; monopotassium phosphate; potassium acid phosphate.

#### Uses

The monobasic salt is a buffering agent for pH measurement and a phar-

maceutical buffer. The monobasic and the dibasic salts mixed to form potassium tripolyphosphate [13845–36–8], a surfactant in laundry detergents.

### Physical Properties

Colorless crystals or white granular powder; tetragonal structure; deliquesces; density 2.338 g/cm<sup>3</sup>; melts at 252.6°C; soluble in water 33 g/100mL at 25°C; pH 4.4–4.7; insoluble in alcohol.

### Preparation

Monopotassium phosphate may be prepared by partial neutralization of phosphoric acid with potassium hydroxide in equimolar amounts:



### Analysis

Elemental composition: K 28.73%, P 22.76%, H 1.48%, and O 47.03%. Potassium content of the salt can be measured by various instrumental methods (see Potassium). The phosphorus content of the salt can be measured in its aqueous solution by colorimetric methods (see Phosphorus).

## POTASSIUM PHOSPHATE, TRIBASIC

[7778–53–2]

Formula: K<sub>3</sub>PO<sub>4</sub>; MW 212.27

Synonyms: tripotassium phosphate; potassium orthophosphate

### Uses

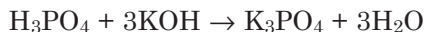
The tribasic salt is a water softener; emulsifier; and a nutrient for yeast production and wine fermentation.

### Physical Properties

Colorless orthorhombic crystals; deliquescent; density 2.564 g/cm<sup>3</sup> at 17°C; melts at 1,380°C; very soluble in water, 90 g/100mL at 20°C; aqueous solutions strongly alkaline; insoluble in alcohol.

### Preparation

The tribasic salt is produced by complete neutralization of phosphoric acid with potassium hydroxide, followed by evaporation and crystallization:



### Analysis

Elemental composition: K 55.25%, P 14.59%, O 30.15%. The salt is dissolved in water for potassium analysis (see Potassium) and colorimetric determination of phosphate ion (see Phosphoric Acid).

## POTASSIUM SORBATE

[24634–61–5]

Formula:  $\text{CH}_3\text{CH}=\text{CHCH}=\text{CHCOOK}$ ; MW 150.22

Synonyms: potassium 2, 4–hexadienoate; sorbic acid potassium salt; 2, 4–hexadienoic acid potassium salt.

### Uses

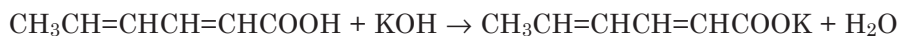
The compound is an inhibitor of yeast and mold growth in water.

### Physical Properties

Colorless or white crystalline solid; density 1.36 g/cm<sup>3</sup>; decomposes at 270°C; soluble in water, 58 g/100 g solution; moderately soluble in alcohol.

### Preparation

Potassium sorbate is prepared by reacting potassium hydroxide with sorbic acid, followed by evaporation and crystallization:



### Analysis

Elemental composition: K 26.03%, C 47.97%, H 4.70%, and O 21.30%. The salt is dissolved in water and analyzed for potassium by various methods (see Potassium). A diluted alcoholic solution may be analyzed by GC/MS. The characteristic masses for this compound are 111, 112.

## POTASSIUM SULFATE

[7778–80–5]

Formula:  $\text{K}_2\text{SO}_4$ ; MW 174.25

Synonyms: sal polychrestum; arcanum duplicatum

### Occurrence and Uses

Potassium and sodium sulfates and their double sulfates with calcium and magnesium occur naturally in various salt lakes. Potassium sulfate also occurs in certain volcanic lava. Its double salt with magnesium occurs in nature, as the mineral langbeinite.

Potassium sulfate is used in fertilizers as a source of potassium and sulfur, both of which are essential elements for plant growth. Either in simple form or as a double salt with magnesium sulfate, potassium sulfate is one of the most widely consumed potassium salts in agricultural applications. It is preferred over potassium chloride for certain types of crops; such as, tobacco, citrus, and other chloride-sensitive crops. Some other applications include making gypsum cements; to make potassium alum; in the analysis of Kjeldahl nitrogen; and in medicine.

### Physical Properties

Colorless or white crystals or white granules or powder; rhombohedral structure; bitter taste; density 2.66 g/cm<sup>3</sup>; melts at 1,069°C; vaporizes at 1,689°C; moderately soluble in water, 12 g/100mL at 25°C and 24g/100mL at 100°C; slightly soluble in glycerol; insoluble in alcohol, acetone, and carbon disulfide.

### Thermochemical Properties

|                    |                  |
|--------------------|------------------|
| $\Delta H_f^\circ$ | -343.6 kcal/mol  |
| $\Delta G_f^\circ$ | -315.8 kcal/mol  |
| $S^\circ$          | 42.0 cal/deg mol |
| $C_p$              | 31.4 cal/deg mol |

### Production

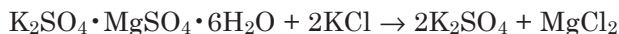
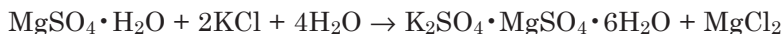
Potassium sulfate is produced by various methods, selection of process depending on availability and cost of raw materials.

The salt may be obtained from its naturally occurring mineral, langbeinite,  $K_2SO_4 \cdot 2MgSO_4$ . The ore first is crushed and washed with water to separate sodium chloride. After that, magnetite is separated from the washed langbeinite by magnetic separation. After the separation of these two major impurities, the purified double salt is treated with an aqueous solution of potassium chloride to obtain potassium sulfate:



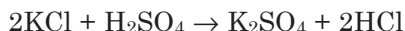
The solution is filtered to remove insoluble residues and the products are separated from their aqueous mixture by crystallization.

Potassium sulfate also is produced from the mineral kieserite,  $MgSO_4 \cdot H_2O$  by treatment with potassium chloride. The intermediate double salt obtained reacts further with potassium chloride to form potassium sulfate:



Potassium sulfate is separated from the more soluble magnesium chloride by crystallization.

Also, potassium sulfate can be made by two other processes in which no naturally occurring mineral is employed. In the Mannheim process, the salt is produced by action of sulfuric acid on potassium chloride:



In Hargreaves process, which is a slight variation of the Mannheim method, potassium sulfate is made by heating a mixture of potassium chloride, sulfur dioxide, air and water:





### Analysis

Elemental composition: K 44.87%, S 18.40%, and O 36.73%. Potassium content may be determined by analyzing an appropriately diluted aqueous solution for the metal by AA, ICP, or other instrumental methods (see Potassium). The sulfate concentration may be measured by ion chromatography or gravimetry following precipitation with barium chloride.

## POTASSIUM THIOCYANATE

[333–20–0]

Formula: KSCN; MW 97.18

Synonyms: potassium sulfocyanate; potassium rhodanide

### Uses

Potassium thiocyanate is used in dyeing and printing textiles; to make artificial mustard oil; as a slimicide in paper production; for controlling microbial growth in cooling water; and in the preparation of organic thiocyanates. The salt also is used in analytical chemistry in Volhard titration.

### Physical Properties

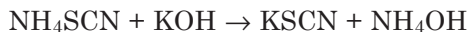
Colorless rhombohedral crystals; deliquesces; density 1.886 g/cm<sup>3</sup> at 15°C; melts at 173.2°C, the color of the fused salt changing from brown to green and then blue; turns white again on cooling; decomposes at about 500°C; very soluble in water, 177 g/100mL at 0°C and 217 g/100mL at 20°C; solution cools upon dissolution; aqueous solution neutral; readily dissolves in acetone and liquid ammonia; moderately soluble in hot alcohol.

### Thermochemical Properties

|                    |                   |
|--------------------|-------------------|
| $\Delta H_f^\circ$ | –47.84 kcal/mol   |
| $\Delta G_f^\circ$ | –42.62 kcal/mol   |
| $S^\circ$          | 29.70 cal/deg mol |
| $C_p$              | 21.16 cal/deg mol |

### Preparation

Potassium thiocyanate may be made by adding caustic potash to a solution of ammonium thiocyanate, followed by evaporation of the solution.



Also, the compound can be prepared by heating potassium cyanide with sulfur:



### Reactions

The reactions of potassium thiocyanate in aqueous solution are essentially those of the thiocyanate anion. Its reaction with ferric ammonium sulfate, applied in Volhard titration, results in the formation of ferric thiocyanate,  $\text{Fe}(\text{SCN})_3$ . Similarly, in titration against silver nitrate, it forms insoluble silver thiocyanate,  $\text{AgSCN}$ .

Potassium thiocyanate reacts in aqueous solution of ethylene oxide to form ethylene sulfide,  $\text{C}_2\text{H}_4\text{S}$ .

Reactions with trialkylboranes yield the corresponding alkyl thiocyanate,  $\text{RSCN}$ .

### Analysis

Elemental composition: K 40.23%, S 33.00%, C 12.36%, N 14.41%. Potassium can be measured in an aqueous solution by flame photometry, AA, or ICP/AES (see Potassium). Thiocyanate anion can be measured by Volhard titration against a standard solution of silver nitrate in the presence of ferric ammonium sulfate. The color of the solution turns red at the end point.

## POTASSIUM TRIIODO MERCURATE(II)

[22330-18-3]

Formula:  $\text{KHgI}_3$ ; MW 620.40

Synonyms: potassium mercuriiodide; mercuric potassium iodide. Its aqueous solution also is known as Channing's solution or Thoulet's solution.

### Uses

The compound is prepared and marketed only in aqueous solution. It is used mostly as a disinfectant and a topical antiseptic. Also, it is used to make Nessler's reagent for analyzing ammonia, and as an analytical reagent for alkaloids.

### Physical Properties

Yellow, deliquescent crystals; melts at  $150^\circ\text{C}$ ; very soluble in water and alcohol; soluble in potassium iodide solution, acetic acid and ether.

### Preparation

The commercial product is made and sold as an aqueous solution by dissolving 1g mercuric iodide and 0.8g potassium iodide in 100mL water:



### Toxicity

The complex salt or its aqueous solution is toxic by ingestion.